*Section instructor*_____   *Section number*_____

*Last/First name*___*Daugherov A.*_____

Last 3 Digits of Student ID Number: _____

Show all work. Show all formulas used for each problem prior to substitution of numbers. Label diagrams and include appropriate units for your answers. You may use an alphanumeric calculator during the exam as long as you do not program any formulas into memory. By using an alphanumeric calculator you agree to allow us to check its memory during the exam. Simple scientific calculators are always OK!

A Formula Sheet Is Attached To The Back Of This Examination
Be Prepared to Show your Student ID Card

Score on each problem:

1. (30) _____

2. (20) _____

3. (20) _____

4. (20) _____

5. (20) _____

6. (20) _____

7. (20) _____

Total Score (out of 150 pts) _____

Department of Physics and Applied Physics

University of Massachusetts Lowell
UMASS Lowell

1. Conceptual Questions (30 point)

1.1. (6pts) *A lens produces a sharply focused, inverted image on a screen. What will you see on the screen if the lens is covered by a dark mask having only a small hole in the center?*

A. *An inverted but blurry image.*

B. *An image that is dimmer but otherwise unchanged.*

C. *Only the top half of the image.*

D. *Only the bottom half of the image.*

E. *No image at all.*
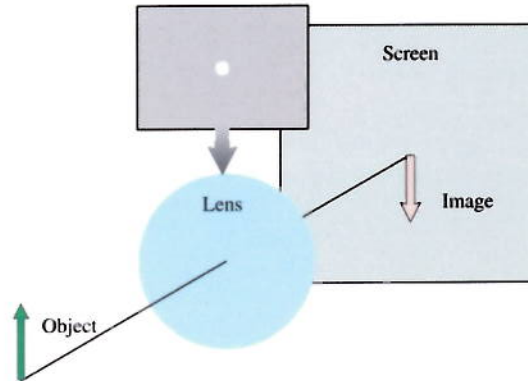
1.2. (6pts) *Figure is a snapshot graph of two plane waves passing through a region of space. Each wave has a 2.0 mm amplitude and the same wavelength. What is the net displacement of the medium at points A and B?*

| Point	Amplitude
A	4 мм
B	0 мм
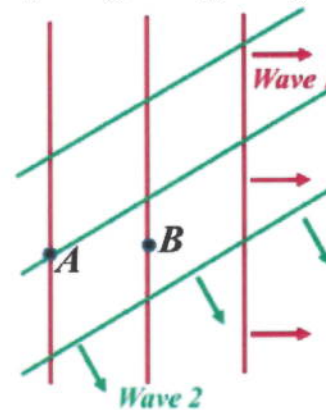
1.3 (6pts) *Four point charges are arranged at the corners of a square. Find the electric field E and the potential V at the center of the square.*

A) *E=0; V=0*

B) *E=0; V≠0*

C) *E≠0; V≠0*

D) *E≠0; V=0*

E) *E = V regardless of the value*

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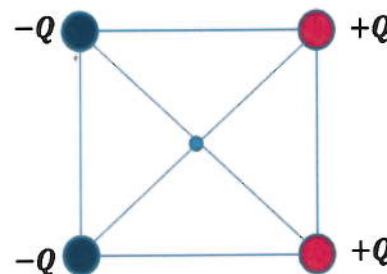
1.4 (6pts) An extended light bulb (see the figure) illuminates a narrow vertical aperture in a dark screen. What do you see on the viewing screen?
(Circle the right answer)

Viewing screen —

Light bulb
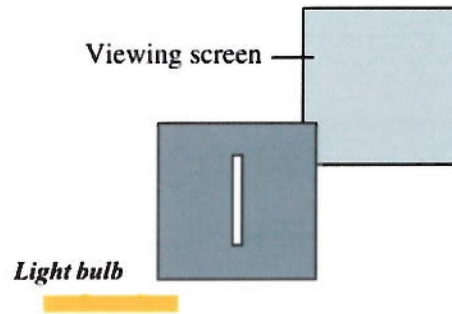
A.   B.   C.   D.   (E.)

1.5 (6pts) Two loops of wire are moving in the vicinity of a very long straight wire carrying a steady current. Find the direction of the induced current in each loop. (CW stands for clockwise direction; CCW – counterclockwise)
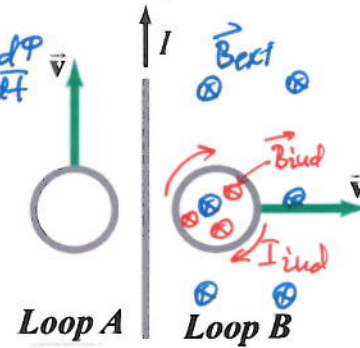
Loop A:
A) CW

B) CCW

(C) No current)

Loop B:

A) CW

B) CCW

C) No current

$B = const$
$A = const$ } $\Phi_B = const \Rightarrow \mathcal{E} = -\dfrac{d\Phi}{dt}$ $\vec{v}$
$\theta = const$

$\mathcal{E} = 0$

I $\vec{B}_{ext}$

$\vec{B}_{ind}$

$\vec{v}$

I_{ind}

Loop A   **Loop B**

$B_{ext}\downarrow \Rightarrow \Phi_B\downarrow \Rightarrow \vec{B}_{ind}\uparrow\uparrow \vec{B}_{ext} \Rightarrow I\,(CW)$

Problem 2. (20 pts)

A 0.1-m-tall cat is placed 20 cm from a 1-m-focal length converging lens.

 a) *Determine the image position using ray tracing (draw it). Identify if the image is upright/inverted and real/virtual.*

 b) *Calculate the image position and height.*

a)

f *image* f
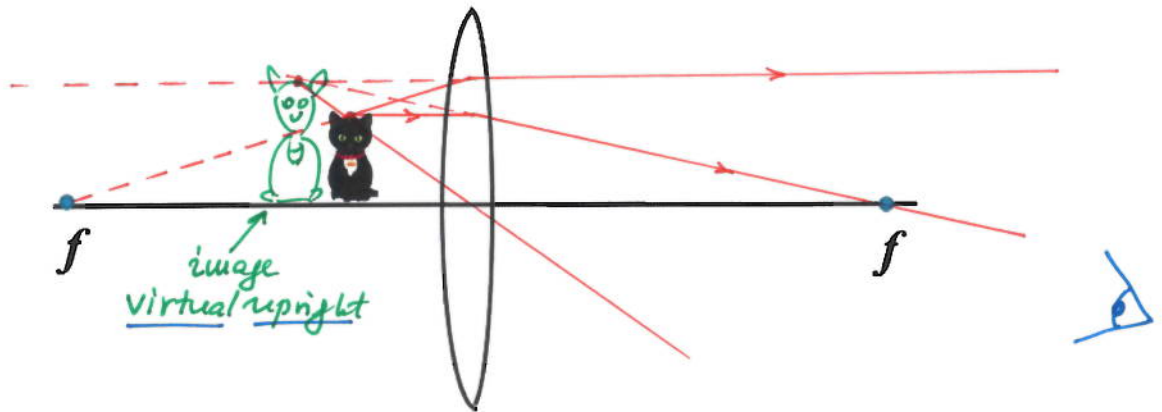
virtual upright

b) $\dfrac{1}{f} = \dfrac{1}{s} + \dfrac{1}{s'}$ $s = 0.2\,m\,;\ f = +1\,m\,;\ h = 0.1\,m$

$s' = \dfrac{s \cdot f}{s - f} = \dfrac{1m \cdot 0.2m}{0.2m - 1m} = \boxed{-0.25\,m}$ ← *virtual image*

$M = -\dfrac{s'}{s} = -\dfrac{(-0.25m)}{0.2m} = \boxed{+1.25}$ ← *upright image*

$|M| = \dfrac{h'}{h} \Rightarrow h' = |M| \cdot h = 1.25 \cdot 0.1m = \underline{0.125\,m}$

Problem 3. (20 pts)

Light strikes a glass plate at an angle of incidence of 60°; part of the beam is reflected and part is refracted. It is observed that the reflected and refracted portions make an angle of 90° with each other (see the figure). What is the index of refraction of the glass?

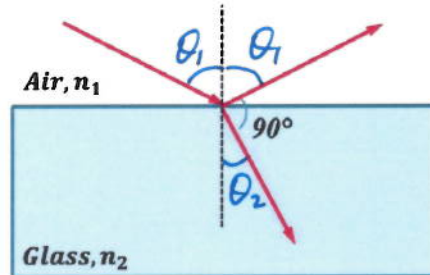$\theta_1 = 60°$

$\theta_1 + 90° + \theta_2 = 180°$ (geometry)

$\theta_2 = 30°$
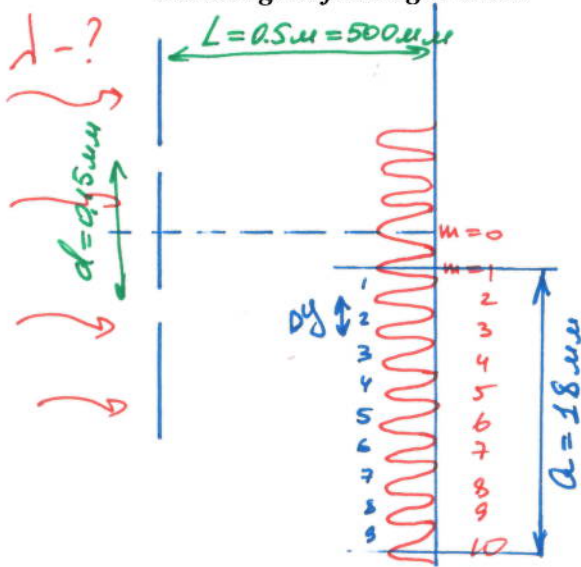
Snell's law:

$$n_1 \cdot \sin \theta_1 = n_2 \cdot \sin \theta_2$$

$$n_2 = n_1 \cdot \frac{\sin \theta_1}{\sin \theta_2} = \left\| \begin{matrix} n_1 = 1 \\ air \end{matrix} \right\| = 1 \cdot \frac{\sin 60°}{\sin 30°} = \frac{\sqrt{3}/2}{1/2} = \sqrt{3}$$

$$\boxed{n_2 = \sqrt{3}}$$

Problem 4. (20 pts)

If the distance between the first and tenth maxima of a double-slit pattern is 18 mm and the slits are separated by 0.15 mm with the screen 50 cm from the slits, what is the wavelength of the light used?

$\lambda - ?$

$L = 0.5 m = 500 mm$

$d = 0.15 mm$

$a = 18 mm$

Given: $d = 0.15 mm$; $a = 18 mm$
$\qquad L = 500 mm$

Find: $\lambda - ?$

$N_{gaps} = N_{bright\ spots} - 1 = 10 - 1 = 9$

Δy - distance (gaps) between bright spots.

$N_{gaps} \cdot \Delta y = a$

$\Delta y = y_{m+1} - y_m = (m+1)\dfrac{\lambda L}{d} - m\dfrac{\lambda L}{d} = \dfrac{\lambda L}{d}$

$N_{gaps} \cdot \dfrac{\lambda L}{d} = a \implies$

$\lambda = \dfrac{a \cdot d}{N_{gaps} \cdot L} = \dfrac{18 mm \cdot 0.15 mm}{9 \cdot 500 mm} = 6 \cdot 10^{-4} mm = \boxed{600\ nm}$

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Problem 5. (20 pts)

The magnetic field of an electromagnetic wave in a vacuum is
$B_z = (2 \cdot 10^{-8} T) \sin[kx + (3\pi \cdot 10^{16})t] ; B_x = 0; B_y = 0$,
where x is in meters and t is in seconds. What are the wave's

    a) *(2pts) direction of propagation;*

$$-x \text{ direction}$$

    b) *(3pts) wavenumber;*

$$c = \frac{\omega}{k} \Rightarrow k = \frac{\omega}{c} = \frac{3\pi \cdot 10^{16} \frac{rad}{s}}{3 \cdot 10^8 \, m/s} = \pi \cdot 10^8 \frac{rad}{m}$$

    c) *(3pts) wavelength;*

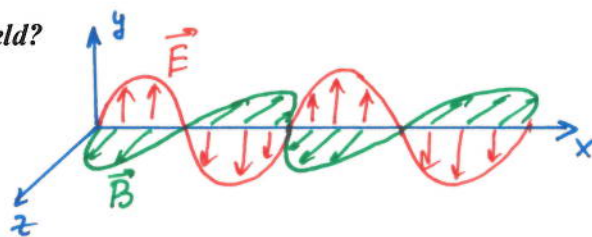$$\lambda = \frac{2\pi}{k} = \frac{2\pi}{\pi \cdot 10^8 \frac{rad}{m}} = 2 \cdot 10^{-8} m$$

    d) *(3pts) frequency;*

$$f = \frac{c}{\lambda} = \frac{3 \cdot 10^8 \, m/s}{2 \cdot 10^{-8} m} = 1.5 \cdot 10^{16} Hz$$

    e) *(3pts) electric field amplitude?*

$$E_0 = c \cdot B_0 = 3 \cdot 10^8 \, m/s \cdot 2 \cdot 10^{-8} T = 6 \, V/m$$

    f) *(3pts) mathematical expression for the electric field?*

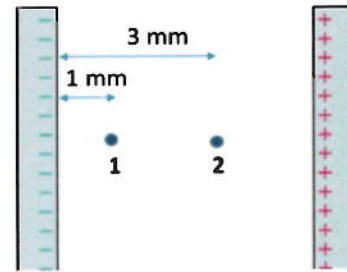$$E_y(x,t) = (6 \, V/m) \cdot \sin\left[(\pi \cdot 10^8)x + (3\pi \cdot 10^{16})t\right]$$

    g) *(3pts) intensity of the electromagnetic wave?*

$$I = \frac{E_0^2}{2c\mu_0} = \frac{(6 \, V/m)^2}{2 \cdot (3 \cdot 10^8 \, m/s) \cdot 4\pi \cdot 10^{-7} \frac{T \cdot m}{A}} = 0.05 \frac{W}{m^2}$$

Problem 6. (20 pts)

A) **(6 pts) The figure shows two points inside a capacitor. Let V=0 V at the negative plate. What is the ratio V_2/V_1 of the electric potential at these two points?**

$$V = E \cdot s \; ; \; E = const$$

$$\frac{V_2}{V_1} = \frac{E \cdot s_2}{E \cdot s_1} = 3$$

B) **(14 pts) An electron is accelerated from rest in a capacitor. A potential difference between the plates is 5000 V. What is the speed of the electron ($m = 9.1 \times 10^{-31}$ kg, $q = -1.6 \times 10^{-19}$ C) as a result of this acceleration?**
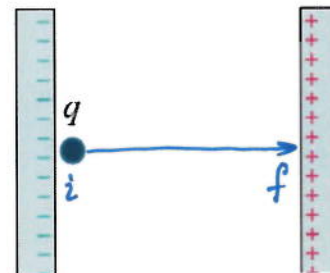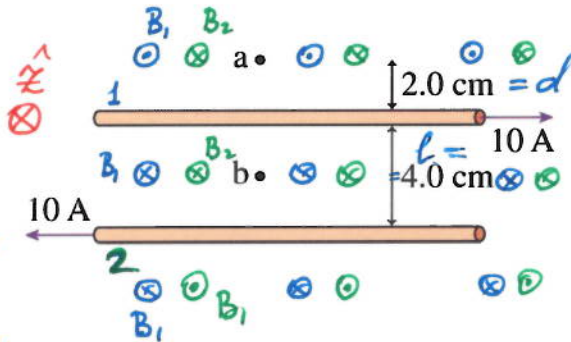
Conserv. of energy

$$E_i = E_f$$

$$K_i + U_i = K_f + U_f \quad \leftarrow U = qV$$

$$\frac{1}{2} m v_f^2 = q(V_i - V_f) = -q\underbrace{(V_f - V_i)}_{\Delta V = 5000 V}$$

$$v_f = \sqrt{-\frac{2}{m} q \cdot \Delta V} = \sqrt{-\frac{2}{9.1 \cdot 10^{-31} kg} \cdot (-1.6 \cdot 10^{-19} c) \cdot 5000 V} = 4.2 \cdot 10^7 \, m/s$$

Problem 7.

A) **(10 pts) What is the magnetic field strength and direction at points a and b in the figure. Point b is the midpoint between the wires.**

$$\boxed{B = \frac{\mu_0 I}{2\pi r}}; \text{ let } \hat{z} \text{ into the page}$$
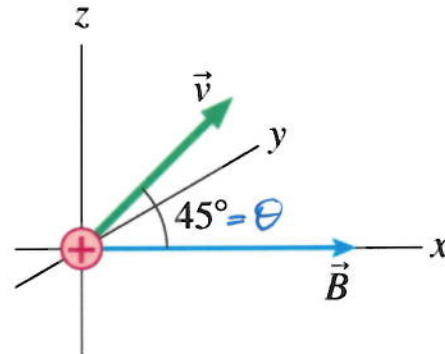
"Point a": $B_1 = \frac{\mu_0 I_1}{2\pi \cdot d}$ (out of the page) $(-\hat{z})$

$$B_2 = \frac{\mu_0 \cdot I_2}{2\pi(\ell+d)} \left(\text{into the page}\right)_{+\hat{z}}; \quad B_1 > B_2 \Rightarrow B_a - \text{out of the page}$$

$$B_a = B_1 - B_2 = \frac{\mu_0}{2\pi}\left(\frac{I_1}{d} - \frac{I_2}{\ell+d}\right) = \boxed{\begin{array}{c}I_1 = I_2\\ = I\end{array}} = \underline{6.7 \cdot 10^{-5} T} \ (\text{out of the page})$$

"Point b"

$$B_b = B_1 + B_2 = \frac{\mu_0}{2\pi} I \left(\frac{1}{\ell/2} + \frac{1}{\ell/2}\right) = \underline{2.0 \cdot 10^{-4} T} \ (\text{into the page})$$

B) **(10 pts) A proton moves in the magnetic field $\vec{B} = 0.5\hat{i}T$ with a speed of $1.0 \times 10^7 m/s$ in the direction shown in the figure. What is the magnetic force on the proton? Give your answers in component form.**

$$\vec{F} = q\vec{v} \times \vec{B}$$

• $\vec{F}$ direction is $+\hat{y}$ (RHR)

○ $\vec{F}$ magnitude

$$|\vec{F}| = |q\vec{v} \times \vec{B}| = qvB \cdot \sin\theta = (1.6 \cdot 10^{-19}C) \cdot (1.0 \cdot 10^7 \, m/s) \cdot 0.50 T \cdot \sin 45° =$$

$$= 5.7 \cdot 10^{-13} N \ (+\hat{y})$$

$$\boxed{\vec{F} = (0; \ 5.7 \cdot 10^{-13}N; \ 0)}$$